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TWENTY YEAR RESULTS OF THE GREAT LAKES - ST. LAWRENCE REGION WHITE SPRUCE PROVENANCE TEST IN NEWFOUNDLAND

by M.A.K. Khalil

NEWFOUNDLAND FOREST RESEARCH CENTRE
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ABSTRACT

An experiment was established in the spring of 1963 in the North Pond Experimental area in east-central Newfoundland to identify white spruce provenances suitable for Newfoundland. Thirty-one provenances from the Great Lakes - St. Lawrence region of Canada and the adjoining areas of U.S.A. with one provenance from the Humber Valley in western Newfoundland were tested in a six-replicated randomized complete block experiment with 40-tree plots using 2 - 2 seedlings planted 1.8 x 1.8 m apart. Height, diameters outside bark at 1.3 m and at half height above 1.3 m were measured on eight randomly selected trees in each plot in the fall of 1978 at the age of 20 years from seed. Form quotients were calculated. Analyses of variance for height, diameter at 1.3 m and form quotient showed that provenances were statistically significant source of variation only for height and diameter. Consequently, Student-Newman-Keul's multiple range tests and single degree of freedom comparisons between meaningful latitudinal classes were conducted for these two variables only. These analyses have indicated the eight best provenances on the basis of height and diameter at 1.3 m.

Trends in variation between 1969 and 1978 have been discussed and juvenile-late correlations have been determined for early selection of superior provenances. Recommendations have been made for future research and development work for white spruce in Newfoundland.

RÉSUMÉ

Une expérience a été mise sur pied au printemps 1963 dans la région expérimentale North Pond dans le centre-est de Terre-Neuve afin d'identifier les provenances d'Épinette blanche convenables pour Terre-Neuve. Trente et une provenances de la région des Grands Lacs - St-Laurent, Canada et des régions adjacentes des É-U., ainsi qu'une provenance de Humber Valley dans l'ouest de Terre-Neuve ont été essayées; les tests ont eu lieu dans un plan complet d'expérimentation en blocs aléatoires à six répétitions, avec des placettes de 40 arbres utilisant des semis 2-2, plantés à 1,8 x 1,8 m de distance. On a mesuré la hauteur, le diamètre à l'extérieur de l'écorce à 1,3 m et à mi-hauteur au-dessus de 1,3 m de huit arbres choisis au hasard dans chaque placette à l'automne 1978 alors que les arbres étaient âgés de 20 ans. Les quotients de forme ont été calculés. Les analyses de variance quant à la hauteur, au diamètre à 1,3 m et au quotient de forme ont montré que les provenances constituaient une source statistiquement significative de variation applicable à la hauteur et au diamètre seulement. En conséquence, des tests à intervalles multiples de Student-Newman-Keul et des comparaisons de simples degrés de liberté entre les classes de latitude significatives ont été appliqué à ces deux seules variables. Ces analyses ont indiqué les 8 meilleures provenances sur la base de la hauteur et due diamètre à 1,3 m.

Les tendances de variation entre 1969 et 1978 ont été discutées et les corrélations jeunesse/maturité tardive ont été déterminées pour la sélection hâtive des provenances supérieures. L'auteur a recommandé des travaux futurs de recherche et de développement pour l'Épinette blanche à Terre-Neuve.

TWENTY YEAR RESULTS OF THE GREAT LAKES - ST. LAWRENCE REGION WHITE SPRUCE PROVENANCE TEST IN NEWFOUNDLAND

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INTRODUCTION

The scarcity of economically useful local tree species, slow growth and problems with natural regeneration in the province of Newfoundland-Labrador emphasize the need for introduction of suitable exotic species and provenances for an effective forest improvement program to increase wood and fibre production for future needs. Though white spruce [Picea glauca (Moench) Voss] is widely distributed in Canada and the northern United States in the Boreal Forest Region as well as other regions (Rowe 1972), it constitutes only 2.3 percent of the volume of the growing stock in Newfoundland-Labrador (Anon. 1974, 1975). Due to wide distribution, high economic value and large genetic variation in the species it has a high potential for genetic improvement. Intensive research on the genetics of white spruce has proceeded since 1950 in Canada and the United States. One such project has been pursued by the Newfoundland Forest Research Centre since 1959 in cooperation with the Petawawa National Forestry Institute to identify suitable provenances for the Province. This is one of the 13 field experiments, comprising selections from 64 provenances from the Great Lakes - St. Lawrence Region of Canada (Rowe 1972) and the adjoining areas of the United States. Ten- and 15-year results of the Newfoundland experiment have been published (Nicholson 1970, Khalil 1974). This report presents the results at the age of 20 years from seed.

MATERIAL AND METHODS

The Provenances

This experiment comprises 32 provenances, 31 of which were obtained from the 10 forest sections of the Great Lakes - St. Lawrence Region (Rowe 1972) of continental Canada and the adjoining areas of the United States, lying between latitudes 43° - 50°N and longitudes 68° - 93°W. They belong to the two clines of the eastern population of the species (Khalil 1974). One provenance was obtained from the Corner Brook Forest Section (B.28b) of the Boreal Forest Region in western Newfoundland (lat. 49.0°N, long. 57.8°W). Khalil (1974) has discussed the ecology and genetics of white spruce as well as the location, physiology and climate of the sites of the above provenances. Their distribution is shown in Fig. 1 and Table 1.

Table 2 summarizes the relevant meteorological data for representative stations for these forest sections and compares them with similar data for Gander, Newfoundland which is the nearest meteorological station to the experiment, located in the North Pond Experimental Area. These data

show that the mean number of frost-free days is lower in the experimental area than in all except four of the sites of the provenances. The mean number of growing days, mean temperature in the May-September period and the mean number of degree-days above 5.6°C are all lower in the experimental area than at the sites of the provenances. The mean rainfall in the May-September period in the experimental area is similar to that in the other forest sections (Anon. 1960, Putnam 1965). Thus, in general, the conditions for growth and development are harsher in the experimental area than at the sites of the provenances. This is also supported by Ouellet and Sherk (1967) according to whom the provenances fall in the plant hardiness zones 4a-7a while the experimental area falls on the boundary of zones 4a and 4b.

The Experiment

Open-pollinated bulked seed from varying number of parent trees in each provenance was used. The experiment is located about the middle of a 10 percent slope along the south side of a shallow valley of the Mint Brook drainage system. The site has a northern aspect and an altitude of about 150 m. The area is underlain with glacial till, and the soil is loamy with sand, silt and clay in the proportion of 44, 48 and 8 percent respectively. The site had carried an 80-year old balsam fir [*Abies balsamea* (L.) Mill]-spruce stand which was clearcut in 1956 and severely burned by wild fire in August 1961. The layout of the experiment and obvious site variations, caused by topography are shown in Fig. 2. However, Nicholson (1970) reported that there were no significant differences in the foliar mineral contents of white spruce growing on the three site types which were distinguished. Thus, the site was fairly homogeneous on the basis of soil nutrition.

The experiment was established in six-replicated randomized complete block design with 40-tree plots arranged in two 20-tree rows. The seedlings which were raised in the Petawawa National Forestry Institute at Chalk River, Ontario (lat. 46.00°N, long. 77.43°W), were spaced 1.8 X 1.8 m. Two border rows were also planted with the same spacing. The Newfoundland provenance consisting of 3 to 5 year old wildlings was planted in the fall of 1963 and the remaining 31 provenances were planted as 2-2 seedlings in the spring of 1963.

The Data Recorded

Eight trees were randomly selected in each plot for measurement, five of which were the same as those selected in 1973. Total height and diameters outside bark at 1.3 m and at half height above 1.3 m were measured on each of the above trees in the fall of 1978 after cessation of the annual growth. Form quotients were calculated for all trees from the above data.

The Statistical Analysis

The following statistical analyses were conducted.

1. Analysis of variance of plot means of height and diameter at 1.3 m to determine the distribution of variation among the different

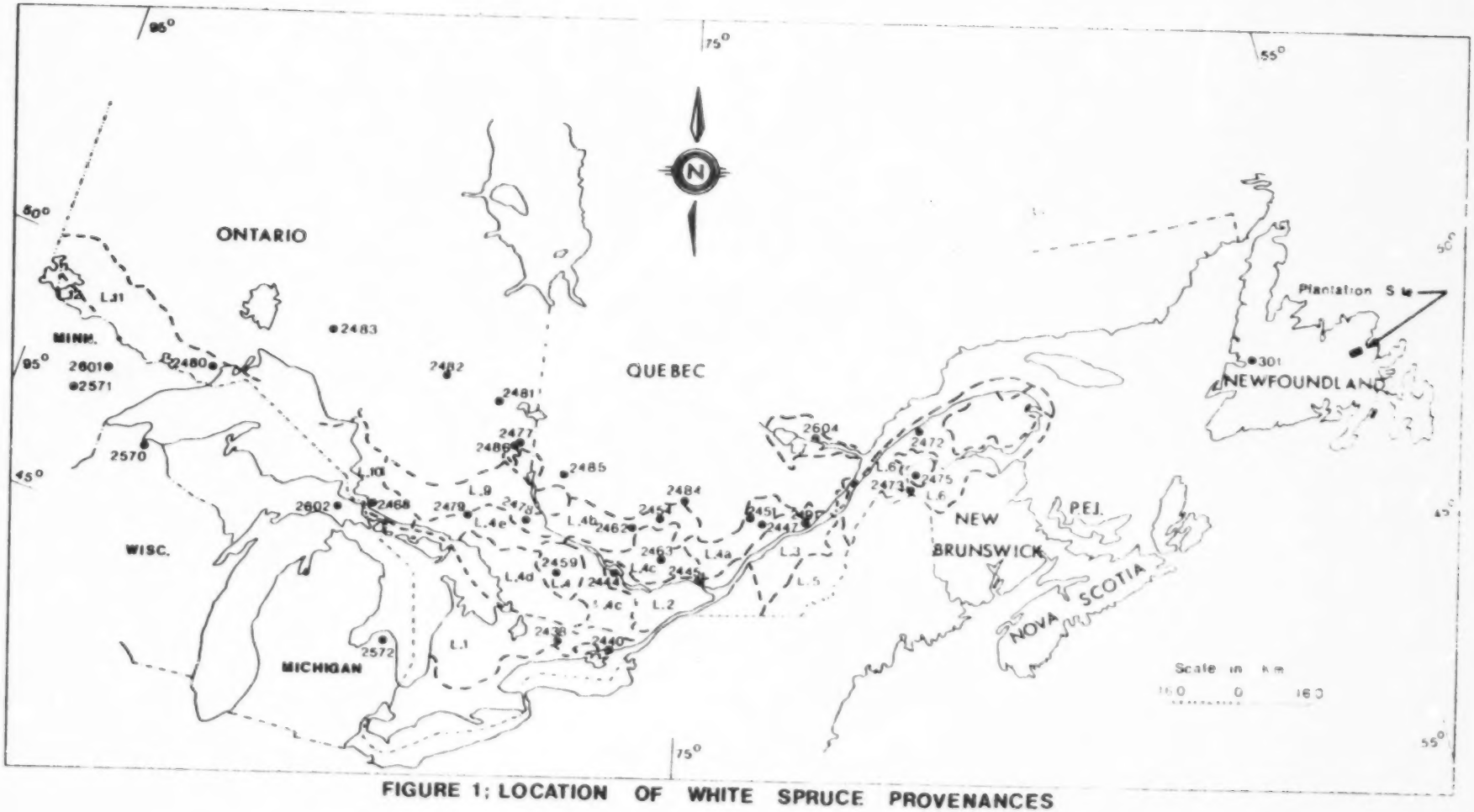


FIGURE 1; LOCATION OF WHITE SPRUCE PROVENANCES

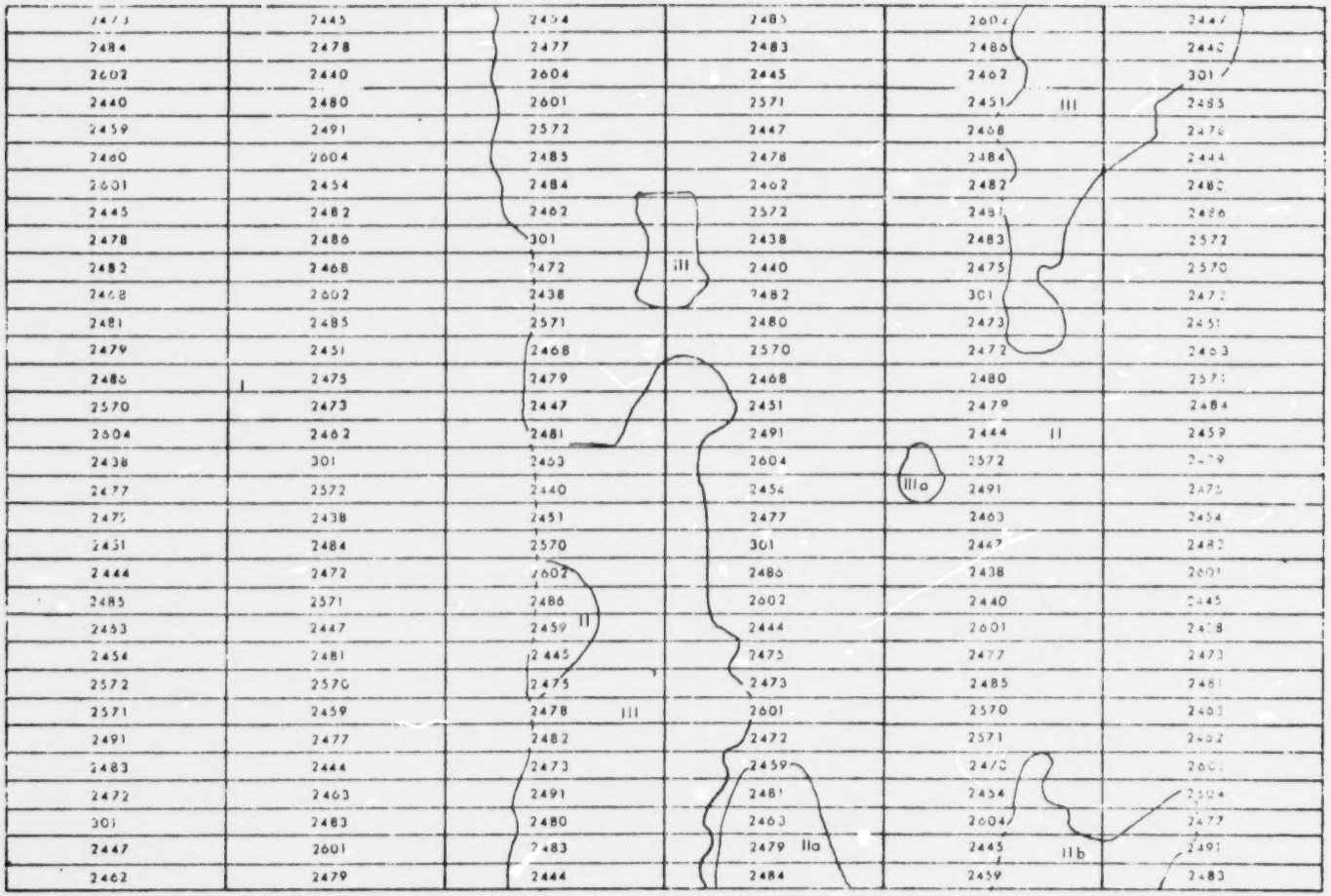
Table 1. Distribution of provenances by Rowe's forest regions and forest sections.

Forest Region	Forest Section	Provenances
Great Lakes - St. Lawrence	L.1 - Huron - Ontario	2438, 2440, 2572
	L.2 - Upper St. Lawrence	2445
	L.4a - Laurentian	2447, 2451, 2484, 2491
	L.4c - Middle Ottawa	2444, 2454, 2459, 2462, 2463, 2485
	L.6 - Temiscouata - Restigouche	2472, 2473, 2475
	L.7 - Saguenay	2604
	L.8 - Haileybury Clay	2477, 2486
	L.9 - Timagami	2478, 2479, 2481, 2482, 2483
	L.10 - Algoma	2468, 2602
	L.11 - Quetico	2480, 2570, 2571, 2601
Boreal	B.28b - Corner Brook	301

Table 2. Selected meteorological data for representative stations in the Great Lakes - St. Lawrence Forest Region and their comparison with those of the experimental area*.

Meteorological factor	North Pond	Forest section										
Station	Gander	L.1 Guelph	L.2 Ottawa	L.4a La Tuque	L.4c Manivaki	L.6 Edmunston	L.7 Roberval	L.8 Earlton	L.9 Bear Island	L.10 Sault Ste. Marie	L.11 Thunder Bay	L.12b Deer Lake
Latitude (°N)	49	44	45	47	46	47	48	48	47	46	48	49
Longitude (°W)	55	80	76	73	76	68	72	80	80	85	89	57
Mean January minimum temperature (°C)	-10	-10	-16	-20	-19	-18	-22	-22	-20	13	-19	-12
Mean date of last spring frost	June 8	May 20	May 12	May 25	May 20	May 31	June 8	June 5	June 3	May 20	June 5	June 10
Mean date of first fall frost	Sept 20	Sept 25	Sept 27	Sept 12	Sept 18	Sept 15	Sept 8	Sept 8	Sept 18	Sept 30	Sept 10	Sept 20
Mean number of frost-free days	103	127	138	109	120	106	91	94	106	132	96	101
Mean date of commencement of growing season (mean temp. above 5.6°C)	May 10	Apr 14	Apr 17	Apr 29	Apr 21	Apr 26	Apr 30	May 1	Apr 28	Apr 26	Apr 30	May 9
Mean date of end of growing season (mean temp. below 5.6°C)	Oct 20	Nov 1	Oct 27	Oct 20	Oct 20	Oct 19	Oct 17	Oct 14	Oct 21	Oct 26	Oct 16	Oct 20
Mean number of growing days	163	201	193	174	182	176	170	166	176	183	169	164
Mean temperature in May - September (°C)	13	17	17	16	16	14	15	14	15	14	14	13
Mean rainfall in May - September (cm)	41	38	38	46	41	48	36	41	41	43	41	43
Mean daily maximum temperature in July (°C)	22	26	27	23	27	24	24	24	25	24	24	22
Degree-days above 5.6°C	1,111	1,695	1,806	1,389	1,389	1,528	1,111	1,250	1,278	1,528	1,389	1,111

*Rowe 1972. Chapman and Brown 1966.



Plantation Description

32 provenances
6 blocks
2 rows of 20 trees in each plot
240 trees per provenance
744 trees in 2 surround rows (Provenance No. 2475)
Tree spacing 1.8 x 1.8 m
Length 224.9 m
Width 132.5
Area 2.8 ha
Planted April 1963 with 2-2 stock

Site Types

I Characterized by fairly deep soil and organic layer, dry-moist vegetation chiefly pin cherry, aspen, Polytrichum with occasional Kalmia.

II Characterized by widely varying soil depths and moisture conditions in localized patches; vegetation is scattered aspen, alder, pin cherry, Polytrichum, Dichranum and occasional bunches of Carex, Viccinium, Kalmia and Cornus.

IIa Like II but with organic material burned off exposing stones and medium-size boulders; dry-moist.

IIb Like IIa but with less organic matter burned off.

III Wet site with muck soil; vegetation is alder, some willow, dense, high Carex spp. with occasional patches of Sphagnum.

IIIa Wet site; vegetation alder with coarse Carex spp.

FIGURE 2: LAYOUT AND SITE DESCRIPTION OF WHITE SPRUCE PROVENANCE EXPERIMENT.

sources and to compare them with the previous results.

2. Ranking and Student-Newman-Keul's multiple range test to determine geographic trends and to identify provenances statistically different from each other.

3. Single degree of freedom comparisons between the following latitudinal zones to determine the existence of statistically significant differences between the provenances of these zones:

   Comparison A - 44°-46°N vs rest
   Comparison B - 44°-46°N vs 46°-48°N
   Comparison C - 44°-46°N vs 48°-50°N
   Comparison D - 46°-48°N vs 48°-50°N

4. Analysis of variance of single tree data for height, diameter at 1.3 m and form quotient to determine the magnitude and statistical significance of replications X provenances interaction.

5. Simple correlations between the mean heights in 1965, 1968, 1973 and 1978 to calculate juvenile-late correlations for determining the possibility of early identification of superior provenances.

RESULTS AND DISCUSSION

Results of the analyses of variance, single degree of freedom comparisons, Student-Newman-Keul's multiple range tests for height and diameters at 1.3 m are shown in Appendices 1-3 respectively. Coefficients of correlations between the heights in 1965, 1968, 1973 and 1978 are presented in Appendix 4. The analysis of variance of form quotient showed provenances to be statistically non-significant source of variation at the 0.05 level. However, replications are significant at the 0.01 level.

These results are discussed below.

Height

Both replications and provenances are statistically significant sources of variation in height at the 0.01 and 0.05 levels respectively. Single degree of freedom comparisons between latitudiual zones show non-significant differences in each of the four comparisons made. Ranking and Student-Newman-Keul's multiple range test shows that the maximum, median and minimum average heights are 309.3 cm, 262.7 cm and 221.7 cm respectively, although trees up to 475 cm exist. Table 3 shows the eight tallest and eight shortest provenances and shows their relative performance with reference to the experiment's mean and the Newfoundland provenance.

Six of the eight best provenances were among the eight best in 1973 also. There have been two notable changes. Provenance 2485, which ranked 7 in 1973 ranked 14 in 1978 and provenance 2472, which ranked 12

In 1973 moved up to rank 5 in 1978. These eight provenances are now significantly superior to the rest at both levels of significance, which they were not in 1973. The lapse of five years has established their superiority. The Newfoundland provenance has moved from 76 percent of the mean in 1973 to 88 percent in 1978. Though this indicates recovery from the initial planting shock this provenance has still to go a long way to establish its superiority compared with the other provenances in the experiment. The eight slowest growing provenances in 1978 were also the same in 1973.

The correlation matrix presented in Appendix 4 is a good indication that superior height at the age of seven years from seed is a reliable indication of similar superiority at the ages of 10, 15 and 20 years. The reduction in the value of the coefficient of correlation with increasing difference in age is expected but its predictive value is retained as long as it is statistically significant at the stated level of significance.

Diameter at 1.3 m

Both replications and provenances are statistically significant sources of variation in diameter at the 0.005 and 0.05 levels respectively. Single degree of freedom comparisons show that only comparison D is statistically significant at the 0.01 level and that the provenances from the 46°-48°N latitudinal zone have attained larger diameters than those from the 48°-50°N latitudinal zone. Ranking and Student-Newman-Keul's multiple range test shows that the maximum, median and minimum average diameters are 42.0 mm, 32.4 mm and 24.5 mm respectively. However, trees with diameters up to 82.0 mm exist. Table 4 shows the relative performance of the eight provenances with the largest and eight provenances with the smallest diameter growth.

Seven of the top eight provenances were also among the top eight in 1973. There have been only two minor changes. Provenance 2481 which ranked 6 in 1973 ranked 12 in 1978 and provenance 2472 which ranked 9 in 1973 moved up to 7 in 1978. As in the case of height the lapse of five years has established the statistically significant superiority of these eight provenances over the rest. There is no change in eight slowest growing provenances between 1973 and 1978.

Combined Results

With one exception, i.e. provenance 2481, the same eight provenances have the greatest height and diameter growth. Analysis of variance of form quotient does not show statistically significant differences among provenances, showing that all of these have equally good stem form. No provenance in the experiment has suffered from frost or winter damage. Hence, the first eight provenances in Table 3 can be accepted as the most suitable ones for east-central Newfoundland.

Table 3. Mean heights of the eight tallest and eight shortest provenances.

Provenances		Mean height (cm)	Percent of experiment mean	Percent of Nfld. proven.
Eight fastest growing provenances				
2447.	Grand Piles, Quebec	309.3	116.9	132.7
2444.	Beachburg, Ontario	306.2	115.7	131.4
2462.	McNally Lake, Quebec	293.7	111.0	126.1
2475.	Upper Green River, N.B.	292.2	110.4	125.4
2472.	Price, Quebec	288.8	109.1	123.9
2451.	Lake Edward, Quebec	283.7	107.2	121.8
2481.	Potter, Ontario	279.2	105.5	119.8
2459.	Algonquin Park, Ontario	279.0	105.4	119.7
Eight slowest growing provenances				
2484.	Mitchinamekus Lake, Quebec	245.7	92.8	105.5
2601.	Cook Co., Minnesota	243.8	92.1	104.6
2468.	Searchmont, Ontario	242.2	91.5	103.9
2604.	Shipshaw River, Ontario	239.8	90.6	102.9
2482.	Kapuskasing, Ontario	239.0	90.3	102.6
2480.	Kakabeka Falls, Ontario	236.3	89.3	101.4
301.	Humber Valley, Newfoundland	233.0	88.0	100.0
2440.	Nepanee, Ontario	221.7	83.8	95.2

Experiment's mean = 264.7 cm

Mean of Newfoundland provenance = 233.0 cm

Table 4. Mean diameters at 1.3 m of the eight fastest and eight slowest growing provenances.

	Provenances	Mean diam. (mm)	Percent of experiment mean	Percent of Nfld. proven.
	Eight fastest growing provenances			
2447.	Grand Piles, Quebec	42.0	132.9	171.4
2444.	Beachburg, Ontario	37.8	119.6	154.3
2462.	McNally Lake, Quebec	37.5	118.7	153.1
2475.	Upper Green River, N.B.	37.2	117.7	151.8
2451.	Lake Edward, Quebec	36.0	113.9	146.9
2463.	Notre Dame du Laus, Quebec	35.7	113.0	145.7
2472.	Price, Quebec	35.5	112.3	144.9
2459.	Algonquin Park, Ontario	35.3	111.7	144.1
	Eight slowest growing provenances			
2601.	Cook Co., Minnesota	27.5	87.0	112.2
2484.	Mitchinamekus Lake, Quebec	27.0	85.4	110.2
2482.	Kapuskasing, Ontario	26.7	84.5	109.0
2468.	Searchmont, Ontario	26.3	83.2	107.3
2480.	Kakabeka Falls, Ontario	25.5	80.7	104.1
2604.	Shipshaw River, Quebec	25.3	80.1	103.3
2440.	Nepanee, Ontario	24.7	78.2	100.8
301.	Humber Valley, Newfoundland	24.5	77.5	100.0

Experiment's mean = 31.6 mm

Mean of Newfoundland provenance = 24.5 mm

Trends in Variation and their Effect on Tree Improvement

Study of the trends in variation, summarized in Table 5 shows that for height, the variation due to replications remained high and statistically significant but decreased from 4.5 percent in 1969 to 3.3 percent in 1978. Similarly, there was a reduction in variation due to provenances from 11.3 percent in 1969 to 9.7 percent in 1978. It had been explained in 1974 (Khalil 1974) that the 1973 results indicated some reduction of the differences in soil conditions among replications as a result of recovery from the differential effects of the 1961 fire as well as an adjustment of the provenances to the differences in the conditions represented by the replications. This explanation has been further supported by the 1978 results.

In case of diameter, though there is reduction in percent variation due to provenances from 1973 to 1978 there is an increase due to replications. This is explained by differences in competition in the different replications due to lack of thinnings. This has reacted opposite to the effect of site conditions which were the only factors operating till 1973.

There is a consistent increase in the replications X provenances interaction in height as well as in diameter. This emphasizes the earlier conclusion of the possibility of enhancing growth by a combination of good provenances and improved environment such as the use of fertilizers (Khalil 1974).

The consistently large among trees within plot variation, which is a reflection of within provenance variations, also supports the earlier conclusion of the potential for increasing growth by further selection within provenances.

CONCLUSIONS

1. The eight fastest growing provenances up to the age of 20 years from seed are 2444, 2447, 2451, 2459, 2462, 2472, 2475 and 2481. As all provenances tested in this experiment are similar in form and are free from frost and winter damage they are now recommended for this region of Newfoundland. They are also provisionally recommended for other areas of the Province, till the results of the all-range provenance study, being established, are available.

2. There is a highly significant replications X provenance interaction associated with height as well as diameter growth. This can be utilized for enhancing growth by using a combination of suitable provenances and good sites and/or fertilizers.

Table 5. Trends in variation from 1969 to 1978.

Source of variation	Percent variation in height by years						Percent variation in diam by years	
	1969	1970	1971	1972	1973	1978	1973	1978
Replications	4.5	4.0	3.5	3.3	3.1	3.3	3.6	5.5
Provenances	11.3	10.6	9.5	9.3	9.1	9.7	11.0	9.8
Replications x Provenances interaction	20.3	22.9	23.3	24.5	25.7	30.4	28.6	30.0
Trees within plots	63.9	62.5	63.8	62.9	62.1	56.6	56.8	54.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

3. Significant within-provenance genetic variation exists which can be used for further genetic improvement of the species by selection of superior trees within superior provenances. The seed and scions from such trees can be used for creation of seed orchards of white spruce in Newfoundland for local production of genetically superior seed of the species.

4. There is a strong correlation between 7-year, 10-year, 15-year and 20-year heights, which can be used for early identification of superior provenances in white spruce in future experiments such as the all-range provenance experiment being established now.

RECOMMENDATIONS FUR FURTHER RESEARCH AND DEVELOPMENT WORK ON WHITE SPRUCE IN NEWFOUNDLAND

Further research and development work on white spruce in Newfoundland on the following lines is suggested for full utilization of the information collected to date:

1. The present provenance experiment in the North Pond Experimental area should be continued up to 40-year age from seed, with remeasurements at intervals of five years.

2. The recently initiated all-range provenance experiment should be pursued so as to supplement the results of the above experiment and study the performance of the western and northern Canadian provenances in insular Newfoundland.

3. Seed orchards of white spruce, now being planned, should include the following:

   i. Open-pollinated progenies from single tree seeds of phenotypically superior provenances identified in this report. This seed can be collected from the original sites or obtained from the Petawawa

National Forestry Institute.

ii. Progenies of inter-provenance hybrids of the above mentioned superior provenances in this experiment produced by crosses in all possible combinations.

4. An experiment should be laid out with the eight best provenances identified in this report to determine the possibility of enhancing growth by using appropriate fertilizers. A five-year greenhouse cum nursery experiment would produce very useful results. The seed for this experiment should be obtained from the original sites or from the Petawawa National Forestry Institute.

5. Seed of successful inter-specific hybrids should be obtained and the seedlings should be tested for suitability to Newfoundland conditions and for resistance to the usual insect pests of white spruce.

6. Progeny trials of the eight superior provenances should be conducted to determine genotypic variation and heritability of important characters in these populations.

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Appendix 1. Results of analysis of variance and single degree of freedom comparisons for height and diameter at 1.3 m based on plot means.

Source of variation	Degrees of freedom	Height (cm)			Diameter at 1.3 m		
		Sum of squares (cm^2)	Mean squares (cm^2)	F	Sum of squares (cm^2)	Mean squares (cm^2)	F
Total	191	363,735			16,395		
Replications	5	27,341 (7.5%)	5,468	3.32**	2,004 (12.2%)	401	5.73***
Provenances	31	81,132 (22.3%)	2,617	1.59*	3,522 (21.5%)	114	1.62*
Comparison A	1	215 (0.1%)	215	0.13^{NS}	11 (0.1%)	11	0.15^{NS}
Comparison B	1	13 (0.0%)	13	0.01^{NS}	12 (0.1%)	12	0.17^{NS}
Comparison C	1	1,800 (0.5%)	1,800	1.09^{NS}	194 (1.2%)	194	2.77^{NS}
Comparison D	1	3,404 (0.9%)	3,404	2.07^{NS}	474 (2.9%)	474	6.76**
Residual	27	75,100 (20.8%)	75,700		2,831 (17.2%)		
Experimental error	155	255,263 (70.2%)	1,647		10,869 (66.3%)	70	

^{NS}Statistically non-significant (0.05 level).
*Statistically significant (0.05 level).
**Statistically significant (0.01 level).
***Statistically significant (0.005 level).

Appendix 2. Student-Newman-Keul's multiple range test for height.

Provenance	Rank	Mean height (cm)	Significant differences at 0.05 level	Significant differences at 0.01 level	Rank in 1973
2447	1	309.3			
2444	2	306.2			
2462	3	293.7			
2475	4	292.2			
2472	5	288.8			
2451	6	283.7			
2481	7	279.2			
2459	8	279.0			
2463	8	279.0			
2477	9	270.8			
2473	10	270.0			10
2491	11	269.7			15
2438	12	268.5			14
2483	12	268.5			11
2485	13	268.2			
2445	14	265.5			
2486	15	264.3			
2572	16	261.0			
2570	17	260.8			
2479	18	260.7			16
2454	19	259.5			23
2571	20	258.0			17
2602	21	257.2			13
2478	22	256.8			20
2484	23	245.7			22
2601	24	243.8			29
2468	25	242.2			31
2604	26	239.8			25
2482	27	239.0			30
2480	28	236.3			24
301	29	233.0			27
2440	30	221.2			32
					28

Note: Provenances joined by the same vertical lines are non-significantly different from each other.

Appendix 3. Student-Newman-Keul's multiple range test for diameter at 1.3 m.

Provenance	Rank	Diam. (mm)	Significant differences at 0.05 level	Significant differences at 0.01 level	Rank in 1973
2447	1	42.0			1
2444	2	37.8			
2462	3	37.5			
2475	4	37.2			
2451	5	36.0			
2463	6	35.7			
2472	7	35.5			
2459	8	35.3			
2491	9	35.0			3
2473	10	33.7			
2445	11	33.5			19
2481	12	33.3			20
2438	13	32.7			
2483	14	32.5			10
2486	14	32.5			
2602	15	32.2			17
2570	16	31.2			15
2485	16	31.2			13
2477	17	30.8			11
2572	18	30.7			14
2454	19	30.3			25
2478	20	29.8			18
2479	21	29.5			23
2571	22	28.8			21
2601	23	27.5			16
2484	24	27.0			29
2482	25	26.7			31
2468	26	26.3			24
2480	27	25.5			26
2604	28	25.3			27
2440	29	24.7			30
301	30	24.5			28
					32

Note: Provenances joined by the same vertical lines are non-significantly different from each other.

Appendix 4. Correlation matrix for height.

	Height in 1965	Height in 1968	Height in 1973	Height in 1978
Height in 1965	1.000			
Height in 1968	0.693**	1.000		
Height in 1973	0.588**	0.846**	1.000	
Height in 1978	0.472**	0.718**	0.874**	1.000

** Statistically significant at the 0.01 level.